DESCRIPTION AND OPERATION OF THE T-SONDE,

A Low-Level Air Temperature Measuring Device

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ABSTRACT

A system to obtain the detailed temperature profiles from the ground surface to heights of 1500–2000 m. has been developed. This economical system employs modified radiosondes and less complex receiving equipment than used at standard radiosonde stations. A simplified approach for obtaining heights by means of a modified baroswitch circuit is also described. The temperature measuring system has performed successfully for two years with reliable results.

1. INTRODUCTION

A system to study the temperature-height relationship in the atmosphere to heights of 1500–2000 m. above the ground has been proposed. Meteorological towers and tethered blimps have been employed for such studies, but each has its height limitation. The U.S. Weather Bureau radiosonde system which observes pressure and humidity as well as temperature is more elaborate and expensive than is believed required. An economical system employing modified radiosondes and less complex receiving equipment has been tested recently by the Weather Bureau at the National Reactor Testing Station [1]. The purpose of this paper is to describe the system and to discuss its performance.

2. DESCRIPTION AND OPERATION

The T-Sonde system consists essentially of a radio transmitter, thermistor, and ground receiving equipment. The transmitter (Signal Corps T69F/AMT–2) consists of the tube 5910 for the relaxation oscillator, the tube JRP–5703 for the radio frequency oscillator, and a single rod antenna. This transmitter emits a frequency-modulated signal with a basic frequency of 403 mc. sec.$^{-1}$ The type of modulator is the relaxation or (squegging) oscillator with a dipole, end-fed antenna.

The transmitter shown in figure 1 was modified by removing the external plug and cord and a permanent jumper was put across the "on" switch from the power supply. The precision fixed resistor which was originally in series with the temperature sensing element was removed, and two ML 405 thermistors were placed in series to form the new temperature sensing element. The two thermistors in series increase the total variable resistance giving the subcarrier oscillator a greater frequency range for the same temperature. This greatly increases the accuracy of the instrument. Finally, leads were brought out for connection to the thermistors and the cover was replaced on the unit.

Equipment at the receiving station includes a radio receiver, an oscilloscope with an elliptical sweep, and a carefully calibrated audio oscillator (fig. 2). The oscilloscope sweep frequency is derived from the audio oscillator, and the T-Sonde subcarrier signal is fed from the receiver to the vertical amplifier of the oscilloscope. In operation, the receiver is tuned to the carrier frequency of 403 mc. sec.$^{-1}$ and the audio oscillator controlling the oscilloscope sweep frequency is adjusted to cause the mark from the T-Sonde subcarrier to stand motionless on the scope's face. Under this condition the T-Sonde subcarrier and audio oscillator frequencies are synchronized. The subcarrier frequency can then be read from the dial of the audio oscillator and referred to the calibration curve for conversion to a temperature reading.

Available as war surplus equipment, the components of the receiving station were relatively inexpensive. The receiver, a Navy RDO APR Series type with a frequency range of 38 to 1000 mc. sec.$^{-1}$ was obtained for \$75 and the RDJ pulse analyzer and oscilloscope cost \$50. The

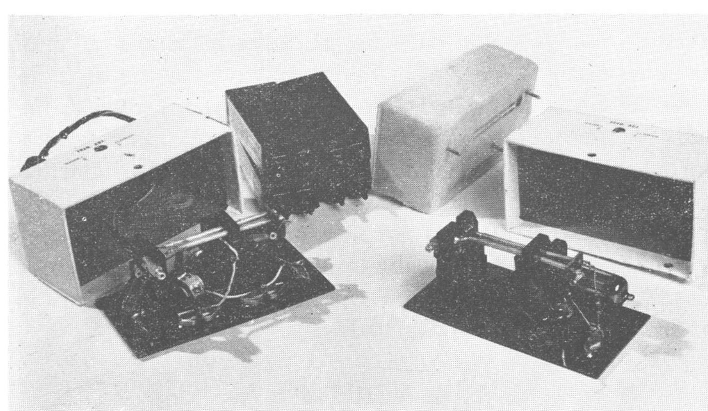

FIGURE 1.—Left—Original radiosonde transmitter and wet-cell batteries. Right—Modified radiosonde and dry-cell battery pack.

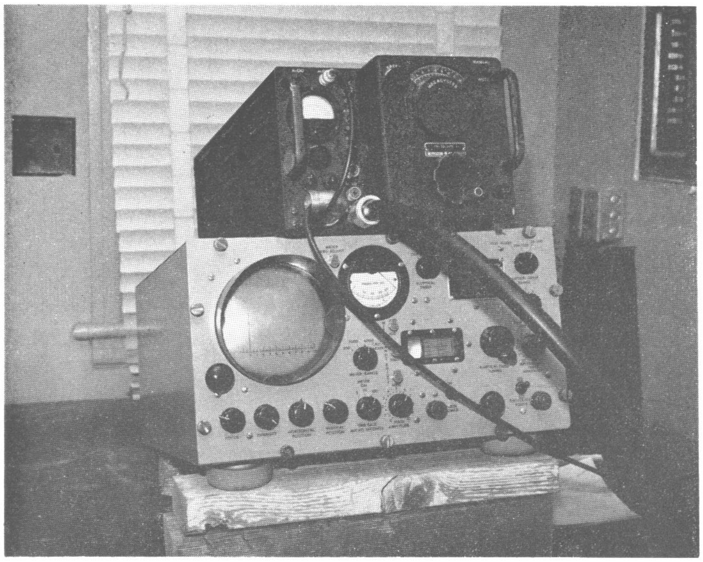

FIGURE 2.—T-Sonde receiving equipment. Top—Radio receiver. Bottom—Oscilloscope and audio oscillator.

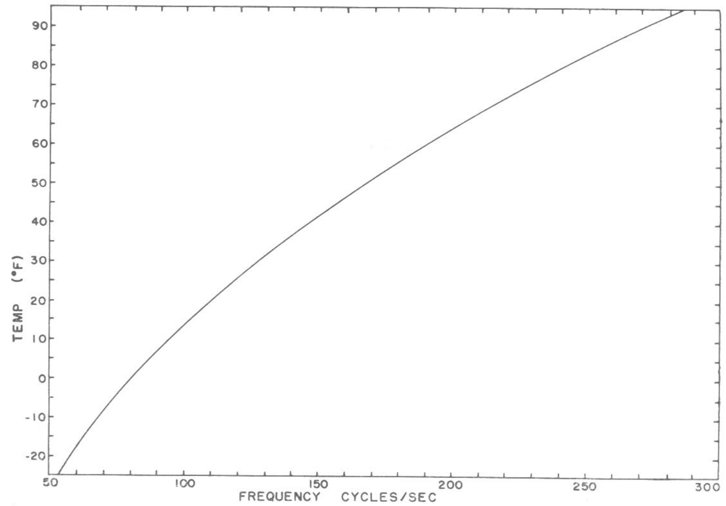

FIGURE 3.—T-Sonde calibration curve using two ML 405 thermistors.

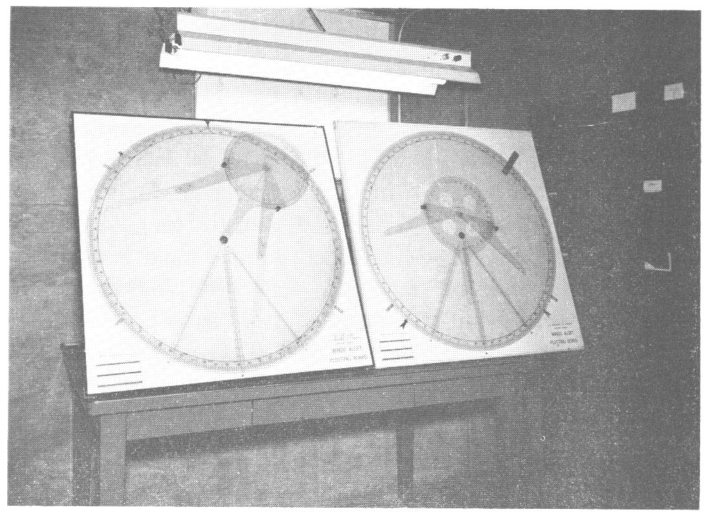

FIGURE 4.—Double theodolite plotting boards. Each board utilizes a different base scale.

transmitters were obtained from surplus property for $1 each and were modified at a cost of $2.50 each.

3. CALIBRATION

An antenna was fitted and power was supplied to the transmitter. After a brief period of warm up for stabilization, the carrier frequency was calibrated at 403 mc. sec.$^{-1}$ with the temperature measuring element (ML 405 thermistors) attached. Then the unit was placed into a calibration medium of xylene, whose temperature can be effectively varied from $-20°$ to $100°$ C. A series of simultaneous readings of temperature and transmitted frequency were recorded for temperatures ranging from $-18°$ to $50°$ C., and calibration curves such as shown in figure 3 were plotted for specific transmitter-thermistor combinations. By calibrating the thermistor with the transmitter used in the flight, optimum accuracy should be achieved.

Since the T-Sonde transmitters are modified standard radiosondes, the resulting error of the T-Sonde should be quite similar to that of the radiosonde whose overall probable error is $\pm 0.5°$ C. The error due to the lag constant of the thermistor is reduced with the T-Sonde, because the ascent rate is reduced to approximately two-thirds that of the 300 m. min.$^{-1}$ ascent of the normal radiosonde. Estimates of lag error are made in the appendix. Finally, the error introduced by frequency drift of the oscillator will be minimized with the T-Sonde because of the reduced time of the flight and the limited range of temperature observed.

4. VEHICLE

The T-Sonde package consisting of transmitter, thermistor, and battery pack weighs 15 oz. and can be conveniently carried aloft with a helium-filled 100-gm. pilot balloon. The battery pack consists of two 45-volt Radio B batteries (miniatures), one 22½ volt B battery (miniature), six 1½ volt pen light batteries for a total of 112½ volts of B batteries, and 9 volts of A batteries with an approximate operating life of 45–60 min. Tracking the balloon by the double theodolite method provides means of computing the heights of the balloon at 30-sec. intervals following release and also allows computation of wind direction and speed for given levels. A simple and fast way to compute height from double theodolites is with the use of a modified plotting board as shown in figure 4. The addition of a standard radiosonde reel, which has had the pendulum increased in length to give a longer period for the string to unwind, and a paper parachute provides a means of terminating the sounding and recovering the instrument. While this increases the weight of the train to 22 oz., the 100-gm. balloon can still provide the necessary lift.

FIGURE 5.—The T-Sonde train, less balloon, including T-Sonde transmitter and dry battery pack, parachute, and ratchet release mechanism.

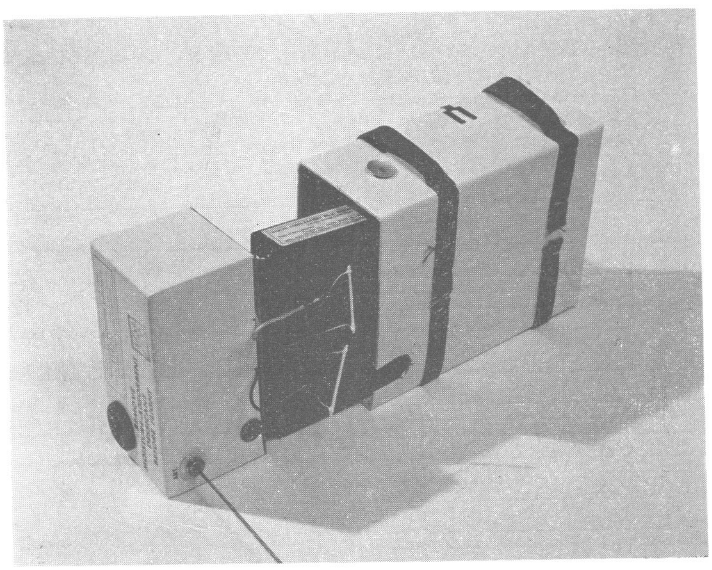

FIGURE 6.—Complete T-Sonde package when wet-cell batteries are used.

The reel is secured to the balloon and the T-Sonde unit is suspended from the parachute. A line from the apex of the parachute is wound on the reel. The length of line wound on the ratchet-controlled reel to attain the desired height was determined by experience by varying the inflation of the balloon with a given pay load. The parachute and T-Sonde train, shown in figure 5, descend when the line is reeled off to permit eventual recovery of the transmitter, thermistor, and parachute. When lead-acid standard radiosonde 6-cell type batteries were substituted, the pay load was increased to 35 oz. (fig. 6). The greater pay load required inflation of the 100-gm. balloon to near the bursting limit to provide an ascent

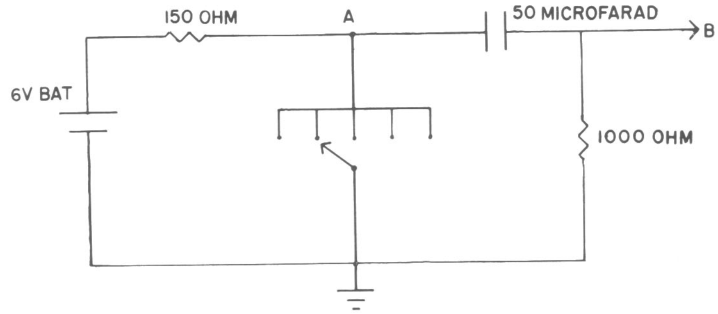

FIGURE 7.—The T-Sonde baroswitch circuit to utilize all contacts on the commutator bar; the standard baroswitch circuit was modified as shown.

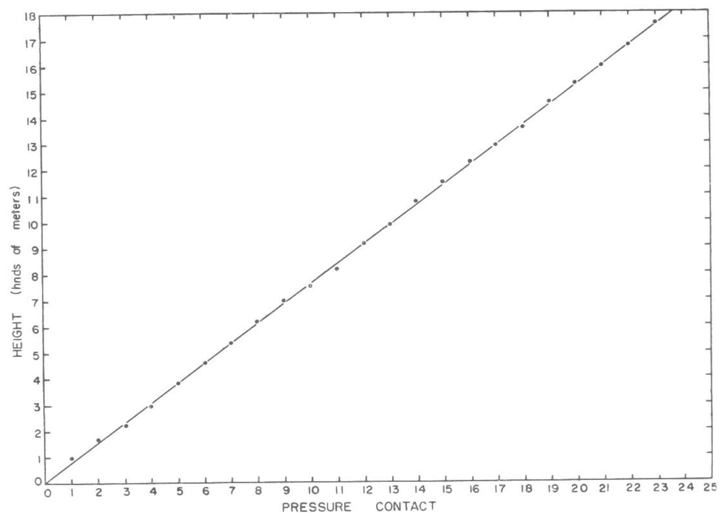

FIGURE 8.—Height versus contact curve resulting from positioning of the transmitter by double theodolite method at each consecutive contact break on the commutator bar.

rate of 200 m. min.$^{-1}$ Hence, for 7-min. flights of 1500 m. with the greater pay load, 300-gm. balloons are more desirable.

The T-Sonde is essentially an all-weather system restricted only by extensive low clouds. The use of a tethered balloon is more seriously restricted by strong winds, which make handling the balloon difficult as well as limiting the height attainable.

5. HEIGHT TRANSDUCER

Recent research and development work has been done with regard to using the baroswitch to obtain heights. The standard baroswitch circuit has been modified [2] as shown in figure 7. The 6-volt filament battery supplies voltage to the commutator switch through a 150-ohm current-limiting resistor. When the commutator bar is shorted to ground by the wiper the voltage at point A is zero. At the instant the wiper leaves the commutator bar approximately 6 volts appear at point A and point

B. The voltage at point B then quickly returns to zero when the 50-microfarad capacitor becomes charged through the 1000-ohm and 150-ohm resistors. This short pulse of voltage at point B causes a chirp which is a momentary increase in the frequency indicated on the scope. When the contact arm reaches another segment of the commutator, the 50-microfarad capacitor is discharged through the 1000-ohm resistor. This produces another chirp which is a momentary decrease in frequency indicated on the scope. While this momentary chirp is indicated on the oscilloscope, the temperature transmission is maintained as a continuous signal.

The results of runs showing the chirp number corresponding to height, as indicated by many flights, have shown that when the baroswitch is set on the same contact number at release, each set of curves has the same slope as indicated in figure 8. Thus it is possible to obtain an estimation of height and temperature simultaneously without the use of double theodolite or pressure-height curves. More testing of procedures and accuracies is planned before final adoption of the system.

6. CONCLUSIONS

Examination of the T-Sonde data for the initial flights has been encouraging. Plots of temperature versus height display curves which are as expected for the particular time of day. It is the purpose of the program to investigate the height and intensity of such stable atmospheric layers and to relate the temperature distribution to the intensity of turbulence in the boundary layer atmosphere.

It is concluded that the system observes the temperature of elevated layers with reasonable accuracy, and that the resulting temperature-height curves derived from the soundings for different times of day are consistent with radiation and turbulent phenomena in the lower atmosphere.

ACKNOWLEDGMENTS

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APPENDIX

The equation for the temperature, θ, of a measuring element with the air temperature, θ_e, changing at a constant rate; i.e.,

$$\theta_e = \theta_1 + \beta t$$

is

$$\frac{d\theta}{dt} = -\frac{1}{\lambda}\left[\theta - (\theta_1 + \beta t)\right].$$

Integration with the assumption that the thermistor is in equilibrium upon release gives

$$\theta - \theta_e = -\beta\lambda\ (1 - e^{-t/\lambda})$$

where λ is the lag constant of the thermistor. After a time $t >> \lambda$, $\theta - \theta_e = -\beta\lambda$.

Therefore, for the error to be large λ must be large. λ varies inversely with the flow rate past the measuring element. Time constants obtained from figure 4 of Sion's [3] article are used to compute the errors due to lag and are shown in table 1. Since we are concerned only with temperature differences, every temperature can be compared after the first few seconds.

TABLE 1.—*Temperature error due to lag, 0.018 in. diameter, coated thermistor, 800 mb.*

Rate of ascent (ft./min.)	λ (sec.)	Temp. error due to time lag (° F.)	Equivalent temp-altitude phasing error (ft.)
Temperature gradient 20° F./100 ft.			
1000	2.00	6.6	33.2
600	2.45	4.9	24.5
150	4.00	2.0	10.0
Temperature gradient 5° F./100 ft.			
1000	2.00	1.69	33.2
600	2.45	1.22	24.5
150	4.00	0.50	10.0
Temperature gradient 0.36° F./100 ft.			
1000	2.00	0.12	33.2
600	2.45	.088	24.5
150	4.00	.036	10.0

REFERENCES

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3. Elio Sion, "Time Constants of Radiosonde Thermistors," *Bulletin of the American Meteorological Society*, vol. 36, No. 1, Jan. 1955, pp. 16–21.